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## Databases and ontologies

# The JWS online simulation database

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## Abstract

**Summary:** JWS Online is a web-based platform for construction, simulation and exchange of models in standard formats. We have extended the platform with a database for curated simulation experiments that can be accessed directly via a URL, allowing one-click reproduction of published results. Users can modify the simulation experiments and export them in standard formats. The Simulation database thus lowers the bar on exploring computational models, helps users create valid simulation descriptions and improves the reproducibility of published simulation experiments.

**Availability and Implementation:** The Simulation Database is available on line at <https://jjj.bio.vu.nl/models/experiments/>.

**Contact:** jls@sun.ac.za.

## 1 Introduction

JWS Online is a web-based repository for curated mathematical models of biological systems (Olivier and Snoep, 2004). It supports construction, simulation and exchange of models in standard formats. In addition, JWS Online offers curation services for scientific journals, with secure access to models under review, and it allows the linking of models to experimental data files stored in the FAIRDOMHub (Wolstencroft *et al.*, 2016), (<https://fairdomhub.org/>).

A much-neglected problem in scientific publications is the reproducibility of simulation figures. Even for models that have been made available in a standard format, e.g. Systems Biology Markup Language (SBML) (Hucka *et al.*, 2003), it is often hard to reproduce simulation figures due to incomplete specification of simulation and plotting conditions, (i.e. frequently, figures do not consist of a direct plot, but rather of some ill-specified function of state variables). In addition, experimental data are rarely made available in electronic format, making it hard to re-plot them.

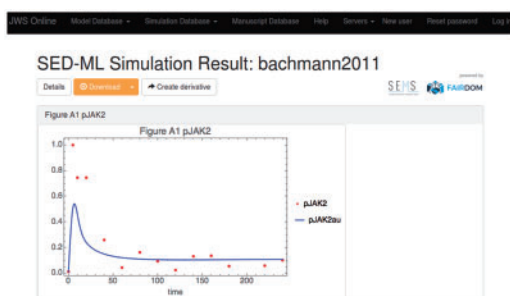
To overcome these issues, the COMBINE community (<http://combine.org>) introduced two new standards. The Simulation Experiment Description Markup Language (SED-ML) (Waltemath *et al.*, 2011) describes all necessary steps to simulate models and to compute and plot results. The second standard is the COMBINE archive (Bergmann *et al.*, 2014), a zip-based container format to

bundle all files necessary to execute a simulation study. Libraries to read and write these standards are available, e.g. libSEDML (<http://libsedml.sourceforge.net>). Despite wide support for these standards in software tools, no repository exists to store simulation studies, except for demonstration files in software tools (e.g. SED-ML Web Tools) or as supplemental material for published models e.g. in BioModels (<https://www.ebi.ac.uk/biomodels-main/>) or the Physiome Model Repository (<https://models.cellml.org/>). To improve this situation, we extended JWS Online with a Simulation Database, and it now offers the first public repository of SED-ML files with the infrastructure to search for simulation studies, link them efficiently to other model-related data, and has the capability of recording and storing provenance information.

## 2 The JWS online simulation database

The JWS online simulation database is a dedicated repository for simulation studies. For user documentation, see: <https://jws-docs.readthedocs.io>. Its main features are:

**One-click figure reproduction:** A URL to an entry in the simulation database directly simulates the model and reproduces a manuscript figure. For example, the results shown in Figure 1



**Fig. 1** SED-ML simulation result. The simulation description instructs the retrieval of the bachmann2011 model (Bachmann et al., 2011) from JWS Online and specifies the model simulation and plotting of the pJAK2 variable, including experimental data for the variable (retrieved from the FAIRDOMHub at [https://fairdomhub.org/data\\_files/1329?version=1](https://fairdomhub.org/data_files/1329?version=1))

can be reproduced by clicking on the link: <https://jij.bio.vu.nl/models/experiments/bachmann2011/simulate>.

**Linking models and simulations:** A growing number of the models in JWS Online are linked to simulation descriptions, which are listed under the ‘Simulations using this model’ tab.

**Creating simulation studies:** The easiest way to create a simulation study is by clicking the ‘Add to Simulation’ button in the JWS Online simulator. This can be done for any model in JWS Online, or for models uploaded in SBML format (Hucka et al., 2003). Alternatively, existing COMBINE archives (or SED-ML files) can be uploaded to the database. Subsequently, simulation studies can be modified, or linked to experimental data.

**Setting user rights:** All user simulation studies are private, i.e. only available to the particular user (as User Simulations) and are stored temporarily (non-registered users) or permanently (for logged-in users). Alternatively, simulation studies can be exported as COMBINE archives and stored off-line.

**Secure links to simulation experiments for manuscript reviewers:** A secure part of the Simulation Database is used to store simulation experiments that reproduce figures in manuscripts under review. Log-in details are provided for the reviewers who can then access the simulation experiments.

### 3 Implementation

The Simulation Database extends the existing JWS online model database with the SED-ML Object Model. The resulting database structure is implemented using Python Django’s ORM (object-relational mapping) capabilities and interfaces a PostgreSQL database instance. The business logic and the front end are implemented using the Django framework (e.g. user and rights management, REST api provider). It is populated by importing SED-ML Level 1 Version 3 (using libSED-ML) or COMBINE archives (using a custom Python library <https://github.com/FreakyBytes/pyCombineArchive>). The ‘look and feel’ of the frontend user interface is achieved with the Bootstrap 3 CSS library and the jQuery JavaScript library. REST endpoints are available for third party applications to interact with the database ([https://jws-docs.readthedocs.io/8\\_rest.html](https://jws-docs.readthedocs.io/8_rest.html)).

Numerical integration of models is performed by the Mathematica backend, which is instructed via a JSON document containing the following: references to the models; the description of the simulation experiment; the MathML expressions for post processing of the simulation results; and, if applicable, links to the experimental data available on the FAIRDOMHub. Users may change any relevant aspects of the simulation description, analyse the effect and store the new simulation experiment in their user space.

### 4 Conclusion

The JWS Online Simulation Database provides standards-compliant and reproducible simulation studies based on the SBML, SED-ML and COMBINE archive formats. The simulation studies can be linked to data sets in the FAIRDOMHub. The database improves the publication process by providing access to reproducible simulation studies via secure links during the review process and openly available links after publication. Links to the simulation studies in the database pave the way toward one-click executable figures in scientific publications.

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*Conflict of Interest:* none declared.

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